

Report of panel on detection of NEOs

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An estimated 1500 near-Earth objects (NEOs) larger than one km in diameter revolve around the sun on short-period orbits that can occasionally intersect the orbit of the Earth, only about 7% of this estimated population has been discovered. The number of these objects that currently come close to Earth on the other hand, is much less than 1000 and observing circumstances are biased in favor of discovery of close-approaching objects. There is about one chance in a thousand that one of the undiscovered \sim 1 km objects is destined to collide with Earth in the next century. Such a collision has the potential of injecting sufficient dark material into the atmosphere to cause a major loss of global crop production and consequent loss of human life.

Present evidence indicates that the cumulative number of NEOs is approximately inversely proportional to their diameter, in the diameter range between 100 m and 1 km. Hence the probability of collision of a \sim 100 m body in the next century is of order 10%. Collision of these objects is capable of producing local to regional catastrophic damage.

The discovery of asteroids and comets and the determination of their orbits has been, by long-standing tradition, an international effort. By agreements through the International Astronomical Union, the maintenance and publication of ephemerides of all numbered minor planets has been the responsibility of the Institute for Theoretical Astronomy (ITA) at St. Petersburg, Russia. The ITA has supported a long-range program of astrometry to upgrade the orbits of known asteroids. The center for receiving observations of newly discovered as well as established asteroids and comets has been the Minor Planet Center, now located at the Smithsonian Astrophysical Observatory at Cambridge Massachusetts. This center collates the incoming observations, assigns designations, calculates preliminary and improved orbits, determines when a minor planet becomes numberable, and publishes the results on a monthly basis in the Minor Planet Circulars (MPCs). The work of observers and orbit calculators throughout the world are published in the MPCs. Most of the immediate dissemination of information on NEOs is nowadays via the Minor Planet Center's MPECs (Minor Planet Electronic Circulars), although initial cometary information is communicated via the IAU Central Bureau for Astronomical Telegrams (IAU Circulars), also located at the Smithsonian Astrophysical Observatory. This system has served to coordinate the existing international effort of discovery of asteroids and comets extremely well, including all work to date on NEOs.

There is a continuing high level of international interest in dedicated NEO surveys. One of the strongest on-going efforts is the Anglo-Australian Near-Earth Asteroid Survey (AANEAS). Located at Siding Spring, New South Wales, AANEAS utilizes several telescopes (Steel, 1995). AANEAS not only reports numerous discoveries of NEOs but also provides crucial followup astrometry and recovery of NEOs found elsewhere, particularly when observations are needed in the southern sky. Another important program of followup astrometry is being carried out in Canada.

A new observing system, utilizing an array of CCDs at the focal surface of a 1-m Schmidt telescope is being developed at Côte d'Azur, France.. This system, which will be dedicated primarily to NEO search, will substantially improve the coverage of the sky needed in NEO surveys.

In Japan, where amateur observers have made significant contributions to discovery and astrometric observations of NEOs, Syuzo Isobe (1994) of the National Astronomical Observatory of Japan has proposed that a network of telescopes belonging to cities and amateurs be equipped with CCD detectors to provide critical astrometric observations of discovered NEOs and to assist in the NEO search. A suitable CCD system is being tested; as many as 47 telescopes with apertures larger than 50 cm potentially could participate in this network.

A working group of the International Astronomical Union, chaired by Andrea Carusi of Italy, has been established to help formulate an international program of surveying for NEOs. Investigators and observatories in Europe are potential participants, and a plan is being developed for use of a 1-m Schmidt telescope at the European Southern

Observatory in Chile in NEO search. In China, funds have been allocated for a 1-m telescope dedicated to an NEO survey.

In the United States, surveys for NEOs are in progress or being developed by four different observing teams. One team, at the University of Arizona, uses a CCD detector on a 0.9-m telescope (the Spacewatch Telescope) and has a 1.8-m telescope under construction for dedicated use in surveying for NEOs. A second team, at Lowell Observatory in northern Arizona, will use an array of CCDs on a 0.6-m Schmidt telescope; observations with this system are expected to begin in early 1996. A third team at the Jet Propulsion Laboratory in Pasadena is developing a CCD camera for use on an Air Force 1-m telescope in Hawaii; this camera may be operational in late 1995. A fourth team, at the University of Arizona, plans to use an array of CCDs on a 0.4-m Schmidt located in southern Arizona.

Advances in the last few years in the development of charge-couple devices (CCDs) as detectors have led to substantial improvement in the projected capability to carry out a systematic ground-based survey of NEOs. Large format, high quantum efficiency, fast readout CCDs have been developed whose performance is now close to the theoretical limit. Use of these detectors on sufficiently large telescopes would enable rapid progress to be made in an international NEO survey.

An international program has been defined that responds immediately to the challenge of discovering potentially threatening NEOs (Shoemaker et al., 1995). It would carry out a census of short-period comets and asteroids larger than 1 km in diameter and seriously address smaller NEOs and long-period comets, as well as develop a broad database of physical observations in order to evaluate the impact hazard.

In order to proceed promptly, maximum use needs to be made of existing telescopes. In particular, collaboration of the U.S. Air Force, using its network of satellite-tracking telescopes, would enhance the undertaking. The Air Force's continued development of large array imaging cameras would also be of value to all participants. The collaboration of the international community, including further development of programs underway in France, Australia, Japan, Canada, China, Russia and for the European Southern Observatory is also encouraged.

The recommended program, based chiefly on further development of existing efforts within the U.S. civilian astronomical community, will accomplish the objective of discovering 60-70% of short-period NEOs larger than 1 km diameter within one decade (by the end of 2006, for funding beginning in FY'96). It will also put into place the assets that will extend completeness above 90% in the following five years, and extend it both further and to smaller objects in subsequent years. Anticipated cooperation from the Air Force and international observing teams could shift the attainment of 90% completeness forward to 2006, and significantly augment capabilities for orbit determination and physical measurements.

The program recommended for the U.S. civilian effort requires investment in search telescopes, detectors, and software to fully utilize current technology. Two dedicated telescopes of about 2-meter aperture are the core of the search system. One of these is already under construction. State-of-the-art CCD focal-plane arrays are required in both telescopes. Acquisition of computers and skilled personnel is required to bring the CCD systems into full operation within three years. One or two existing telescopes near 1-meter aperture, with appropriate advanced focal planes, can round out the survey facilities (capable of both survey work and astrometric follow-up for orbit determination). In addition, availability of roughly half time on a 3- to 4-meter class telescope is needed for physical observations of a representative sample of threatening objects. Enhancement of the capability of the Minor Planet Center will be necessary to coordinate the program and handle the enormously increased discovery rates.

The total cost for the first 5 years of the recommended program is \$24 million for the U.S. component of the civilian effort. Beyond the first 5 years, the annual costs drop down to operations costs of about \$3.5 million per year. Participation of the U.S. Air Force in the survey probably will require a comparable level of funding.

The recommended ground-based NEO survey will discover enormous numbers of Earth-approaching objects down to a few m in diameter. Indeed the vast majority of NEOs found will be less than 100 m in diameter. However, the projected level of completeness of the survey in ten years of operation drops off rapidly at diameters below one km, to about 70% at 0.5 km, about 35% at 250 m, and about 10% at 100 m. Higher levels of completeness could be achieved by investment in an international network of large telescopes and by continuation of the survey beyond the first decade. Even with half a dozen large telescopes, however, about 50 years would be required to achieve 90% completeness to 100 m diameter. Ninety % discovery of 50-m bodies, which can also cause severe local damage, would require a still longer duration survey.

The alternative to ground-based surveys for small NEOs is to monitor near-Earth space for incoming small bodies from space-based sensors (Colella et al., 1991). Such systems would provide only short warning times, typically less than a few weeks, and would need to be maintained indefinitely or until a systematic survey has been completed.

References

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